When recounting the deeds of explorers and geographers in Asia, we ought to cherish the memory of the Italian Marco Polo, the mediæval traveller whose amazing journeys in Asia have never been equalled even by the great travellers who have succeeded him in modern times. The record of Marco Polo's travels has been recently familiarised to English readers by the learned labour of Henry Yule.

A retrospect of brave and successful achievement should encourage travellers to do and to dare more and more. Of the men thus engaged many indeed have injured their health, and some have lost their lives. But all have been sustained under trials by their sense of natural beauty, by their aspirations for the progress of civilisation, and by their zeal in the pursuit of knowledge. It is the masterful force of these high and noble sentiments which impels them, "tot volvere casus, tot adire labores."

On the Hot-lake District and the Glaciers and Fjords of New Zealand.—By W. Lant Carpenter, B.A., B.Sc.

A Review of Oceanic or Maritime Discovery, Exploration and Research, during the half-century, 1831-81. By Captain Sir Frederick Evans, R.N., K.C.B., F.R.S., Hydrographer of the Admiralty.—After a few preliminary observations the paper continued as follows:—

Maritime discovery may be considered—at least so far as this includes regions within the torrid and temperate zones—to have been exhausted some time before the foundation year of the British Association (1831) had been reached, leaving the areas within the Arctic and Antarctic circles as the sole fields for the discovery of new lands to reward maritime enterprise. In both of these frozen areas much has been effected since the year 1831; more especially within that circle which lies the nearest to our own shores—indeed, the discoveries and explorations in the Polar regions of the northern hemisphere will, from their extent and geographical value, as also from a melancholy interest which attaches to their pursuit, and from causes marking the devotion, courage and self-denying labours of many brave men of various nations, deserve and receive from other hands a separate review.

The exploration of the several oceans and seas, with the concurrent charting of their shores and multitudinous islands, have, to the material benefit of Geography and Hydrography, made vast progress within the last half century; and the attendant researches in several branches of science bearing materially on our knowledge of terrestrial physics have been no less marked in their advance. The term hydrography is perhaps more generally associated with marine surveying, or the art of measuring, mapping and describing the coast-line of a country, and the depths of water in its approaches from seaward; and in this limited sense it was pursued by a few individuals of various nations until the early part of this century. The names of our countrymen Cook, Lane, Dalrymple, Mackenzie, Spence, Huddart, Horsburgh, are well known in this field.

Coming, however, to the period under our immediate review, we find that a total change in the aspects and requirements of hydrography has taken place. Marine surveys have far outreached individual efforts, and have come to be considered national duties, and thus fitting works for the supervision of governments. Vast additions to our knowledge of the sea-board of the globe have of course resulted, but it is in the expansion and in the accuracy of details that the greatest gains have been effected.

The necessity of precision in the establishment of the geographical position in latitude and longitude of the principal ports, and of the prominent coast features of the several oceans, has demanded the employment of astronomical instrumental appliances of the highest order; and especially of marine chronometers for the

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transportation of accurate time from some well-determined primary meridian. In the interests of ocean navigation the field of meteorology has been sedulously worked, in order to define and chart the various features in the wind and current systems of the globe, as also the paths of those revolving storms, the dread of seamen in tropical and adjacent seas; the sounding of the greater depths of the oceans has been demanded in the interests of commerce and of science; and consequent on the growing change in the fabric of our fleets of ships from wood to iron, charts of the earth's magnetical elements, as distributed over its surface, form part of the necessary equipment for the intelligent seaman. Such, briefly stated, have been the expanding features of modern hydrography.

To proceed now with the subject proper of our review:—

Oceanic or Maritime Discovery, Exploration and Research. Maritime Discovery.—Discovery within the Antarctic circle embraced in the period under consideration, although not prosecuted in recent years, commands interest. Little or nothing was known of the geography of this vast area before the present century; Cook, in his second voyage [1772–5], in order to solve the then much agitated question as to the existence of an accessible Southern continent, traversed a great extent of its cheerless seas between the parallels of 60° and 70°. After leaving the Cape of Good Hope he twice passed within the Antarctic circle, and subsequently was finally stopped by ice on the 71st parallel in the meridian of 107° W. All doubts as to the existence of Southern continental lands, unless in very high latitudes, were thus removed.

One of the earliest discoveries of land in this century was made in 1831, when Biscoe, with two small sailing vessels, engaged on a South Sea sealing voyage, sighted land on the Antarctic circle in 47°–49° E. longitude; it was of considerable extent, but so closely bound with field ice as not to admit of approach within 20 or 30 miles. This is the "Enderby Land" of geographers, justly named after Biscoe's enterprising employers, the British merchants Enderby. Biscoe had been preceded in the Antarctic seas by the Russian navigator Bellingshausen [1820–21], who—after traversing eastward from the meridian of Greenwich, and being repeatedly baffled by ice in his progress southward—discovered Peter Island and the high land of Alexander, both to the S.S.W. of Cape Horn; and also by the bold seaman Weddell, an officer in the Royal Navy, who in command of two small sailing vessels reached, when to the S.S.E. of Cape Horn, the high latitude of 74½° S., without however in this position seeing land, or indeed very little ice: this is one of the most remarkable voyages made in the Southern seas. In 1832, Biscoe, continuing his mercantile pursuit, discovered to the south of Cape Horn what is known as Graham Land. This high, continuous land, which its discoverer considered to be of great extent, is fronted by a range of islands, on which no living animal was found, except a few birds. Biscoe succeeded in landing on Graham Land, of which he took formal possession. In 1833, Kemp, in a small sealing vessel, observed indications of land some ten degrees of longitude eastward of Enderby Land, with which it is probably continuous, but he was prevented by ice from approaching sufficiently close for examination. In 1839, two of Enderby's whaling ships, commanded by Balleny, discovered to the south of New Zealand the group of three high islands now bearing his name, as also adjacent land "of a tremendous height" covered with snow. Balleny, working to the westward, subsequently sighted a distant land (Sabrina) to the south of King George Sound in Australia.

An impetus was thus given to Antarctic exploration, and between the years 1840–43, government ships from three nations—France, America, Great Britain, under their commanders Dumont D'Urville, Wilkes, and James Ross—had reached high southern latitudes. Their several discoveries of lands were effected chiefly to

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the south of New Zealand and Tasmania: D'Urville [1840] sighting Adélie and Clarie lands on the Antarctic circle, between the 130th and 140th meridians of East longitude; Wilkes [1840] sighting land at intervals to the east and west of those discovered by D'Urville; both navigators being barred in their approaches by formidable barriers of ice.

James Ross, with his two ships *Erebus* and *Terror* [1841], was more fortunate. Proceeding on the more easterly meridian of 170° E., he sighted in latitude 71° an undoubted Antarctic continent (Victoria Land), which he succeeded in tracing to the latitude of 78°. This volcanic region, formed of stupendous mountain ranges, enveloped from base to summit in perpetual ice and snow, culminated in the active volcano Mount Erebus [77½° S.-167° E.], whose crater top towered 12,367 feet above the sea: a neighbouring crater, apparently extinct, Mount Terror, attains an altitude but little inferior (10,884 feet). From the base of Mount Terror a continuous perpendicular wall of ice was traced to the east for nearly 450 miles. This extraordinary barrier of ice, without rent or fissure, and probably a thousand feet in thickness, presented above the sea an almost unvarying level outline elevated from 150 to 200 feet. Ross describes this icy barrier as "a wonderful and mighty object, far beyond anything we could have thought or conceived." The great distance to which the icy plains extended to the south from this their sea margin, was indicated by an intensely blue sky.

Excepting on two small islands (Possession and Franklin) of Victoria Land, Ross, in common with other discoverers, failed to secure permanent landing on this frozen continent; indeed, the gigantic ice cliffs, thrust out from the solid shores, met also by D'Urville and Wilkes in their explorations to the north and west of Victoria Land, would appear to present insurmountable obstacles to land exploration. The breaking up of these grand walls of ice, forming as they do the tabular bergs common to the southern seas,* combined with the apparently rapid formation of pack ice—found to extend in one season several degrees of latitude northward of that experienced in another season—renders even an approach to Antarctic lands a task of uncertainty and difficulty.

Commercial enterprise so far has not been rewarded by the products of the inhospitable lands or the ice-laden seas within the Antarctic circle.

Oceanic Exploration; Progress of Marine Surveys.—In reviewing the subject of oceanic exploration within the last half century, it is perhaps well to premise that at the close of the great wars—Continental and American [1813-15]—there was not only a revival of voyages, undertaken in the interests of science, to distant lands, but the more laboured and patient examination of lines of sea-coast, within specific boundaries, began to engage the attention of many European states. Between these dates and 1831, under the direction of the Hydrographers of the Admiralty—Hurd, Parry, and Beaufort—our own shores, and their approaches from seaward, were being surveyed by Martin, White, Denham, Thomas, and other skilled naval officers; on the lakes of Canada, in the Gulf of St. Lawrence, and in Newfoundland, Admiralty surveyors under Owen, Bayfield, and Bullock were actively engaged; in the Caribbean Sea and among the West India islands, De Mayne and Richard Owen, in surveying ships of good tonnage, were performing excellent service; so also Smyth and Copeland in the Mediterranean; W. F. W. Owen on the east and west coasts of

* About the year 1850, ships engaged in the Australian trade, with the view of shortening the time occupied on the voyage, commenced to shape a route through higher latitudes than former experience warranted. Icebergs, occasionally of considerable horizontal dimensions and in immense numbers, were now frequently encountered. In 1866-74, the Admiralty published Ice-Charts of the Southern Hemisphere for the guidance and warning of seamen.

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Africa; P. P. King on the shores of Australia; and again this officer, with Stokes and FitzRoy as colleagues, on the wild coasts of Tierra del Fuego and Magellan Strait.

In the Indian Ocean, at the instance of the East India Company, marine surveys were being prosecuted on the coasts of Arabia and Persia; in the Bay of Bengal, from the mouths of the Hooghly to Malacca Strait; and a commencement made of the intricate coast details of the Red Sea. The names of Daniel Ross, Moresby, Haines, Brucks, are conspicuous among the Indian naval surveyors of this period. France had commenced (under Beautemps Beaupré) its admirable coast surveys; so also the governments of Norway, Denmark, Sweden, and Russia. Spain was furnished with the labours of the excellent surveyor Tofiño, who performed so much good work at the close of the last century. The United States of America, by Act of Congress in 1832, were organising a coast survey department, which has subsequently executed hydrographic work on both shores of their continent of the highest scientific and practical value.

With this brief, but necessarily imperfect, sketch of the advances of hydrographical work in the early years of this century, we may here pause, and place on record what had been effected in the interests of navigation and commerce, as represented by the charts of the early portion of the period under review. In 1830, the Hydrographic Department of the British Admiralty published its first catalogue of charts, and although hydrography was then, as now, well represented by well-known private firms, especially in London, and whose labours command the respect of all navigators (the names of Norie, Purdy, Laurie, Imray, Findlay, scarcely require quotation), the results of Government surveys were then beginning to supersede the individual labours of some generations of navigators, and maritime charts to assume an authentic and authoritative character under official responsibility.

A comparison of this official record for the year 1830 with a similar record published in 1880 is instructive as to the progress made during these fifty years. The earlier catalogue described 962 charts, the later described 2699. In the appended footnote are given the particulars of their geographical distribution.*

The progress is of course representative of the labours of most of the maritime states of the world; but this country, notwithstanding its vast shipping interests and its corresponding duties, may view with satisfaction the part it has taken in surveying and charting in every ocean and in nearly every sea. Since the year 1831 (under the Hydrographers of the Admiralty) † unintermitted marine surveys have

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Section	1830.	1880.
I. Coasts of United Kingdom	51	368
II. North Sea and coasts	10	53
III. Baltic Sea	14	63
IV. North and West coasts of France, Spain, and Portugal	31	52
V. Mediterranean and neighbouring seas	103	329
VI. Atlantic Ocean and islands	29	56
VII. Arctic Seas; North and East coasts of America	57	302
VIII. Florida Strait, West Indies, Mexico	127	236
IX. South America—East Coast	21	94
X. {South America—West Coast / North America—West Coast}	28	190
XI. Africa, Madagascar, Mauritius, Red Sea	129	231
XII. East Indies, Arabian Coast to Sunda Strait	154	156
XIII. Indian Archipelago, China, Japan	154	265
XIV. Australia, New Zealand	43	204
XV. Pacific Ocean islands	11	100

† Captains, afterwards Admirals, Sir Francis Beaufort, K.C.B, 1828-54; John Washington, 1855-63; Sir George Richards, C.B., 1864-74.

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been maintained on the shores of British North America including Newfoundland; also in our West Indian possessions; and until very recently in the Mediterranean and neighbouring waters; since the year 1837, continuously on the shores of Australia, including a complete examination of the coasts of New Zealand; and since 1842, continuously on the coasts of China, Japan, and among the dangers and the approaches of the China and adjacent seas. Surveying expeditions have visited nearly the whole western seaboard of America, from the Strait of Magellan to Panama, and thence to Behring Strait. The seaboard of British Columbia, with its grand fiords and the valuable island of Vancouver, have been surveyed in detail. In the western Pacific Ocean, in the interests of our Australian colonies, the vast extent of the great barrier reef of Australia has been charted, together with Torres Strait, the eastern part of New Guinea, and its off-lying archipelago; an exhaustive survey of the Fiji group is fast advancing towards completion, and nearly all the dangerous banks in the Coral Sea have been examined.

Passing to Africa, the coast between capes Spartel and Bojador has been charted in ample detail by our surveying ships; so also the extensive seaboard from Cape Verd to the Bight of Biafra, thence to Cape Lopez; and in parts from Walfisch Bay to the Orange River. Between the years 1852-72, Admiralty surveying parties were continuously engaged charting the shores of the Cape Colony, from Orange River on the west to Tugela river on the east; more recently, surveying ships have been engaged on the Zanzibar coast, the seaboard between Pemba, Cape Delgado, and Rás Pekawi being charted in minute detail. Mauritius and its numerous island dependencies, including Rodriguez, have been similarly charted; and consequent on the opening of the Suez Canal, re-surveys of the Gulf of Suez, the Mussawa Channel, and other parts of the Red Sea have been undertaken. These surveys in the Red Sea were made on commensurate scales, to supersede the otherwise excellent charts of the Indian surveyors [1830-4], the details of which did not suffice in the more intricate parts for the conditions of modern steam navigation.

In the Indian seas, the skilled surveyors of the Indian marine preserved a reputation which, by the year 1831, had indeed been well earned, and their labours only ceased when circumstances led to the Crown assuming the government of India in the place of the East India Company. In 1862, the Indian navy ceased to exist. During this period [1831-62] the shores of British India had been well attended to; the Red Sea completed; admirable surveys made of the Maldives and Chagos archipelago; of the coasts of Arabia and the Persian Gulf; of the African coast from the entrance of the Red Sea to Cape Gardafui and thence to Rás Hafun, together with Socotra; while in the Eastern seas, the completion of the Straits of Malacca was a fitting supplement to the honest and laborious work performed in the western approaches to India. In 1874, marine surveys on the shores of British India were again resumed, a special department in Calcutta having been instituted by the Government of India.

If we turn to the labours of other nations, we find that the existing excellent charts of the Baltic and North seas result from contributions of the Governments of all the States situated on their shores; works conducted with the most patient attention to detail: so also on the Atlantic coasts and in the western basin of the Mediterranean and the Adriatic Sea, from contributions by France, Spain, Italy, and Austria. Passing to more distant seas, notably in the Pacific Ocean, we find the ships of the leading maritime states contributing to their hydrography. Spain, and especially the Netherlands, have gradually improved the charts of their Eastern possessions; the Japanese have for some years been engaged (after European models) in charting portions of their coasts; Russia also, in the Gulf of Tartary, in the Sea of Okhotsk, and on the shores of Kamtchatka. It is almost superfluous to descant

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on the admirable contributions of the United States Coast Survey, still steadily at its work on the shores of the two great oceans. Brazil and Chili have in late years established hydrographic bureaus, and are performing good service on their extensive seaboards. In short, progress, both in patient exploration of the shores of the oceans and in attention to all details in the interests of seamen, is almost without exception a marked feature of our time; though hydrographers cannot but regret that the charts of the extensive Portuguese possessions on the west and east coasts of South Africa are not representative of the prevailing spirit.

Ocean Exploration continued: Determination of Longitude.—One of the greatest advances made in modern hydrography has been that of determining the longitude of any particular spot by the transportation of time from some primary meridian. Previously to the time of Cook, the longitudes of newly-discovered lands were either dependent on the rude results of the ship's run or upon lunar observations: about 1770,* the introduction of the marine chronometer (Cook in his second voyage [1772–5] carried four such watches) enabled the scientific navigator to carry the local time obtained at one port of call to another port, and thus to ascertain the time interval between their meridians, or in other words their difference in longitude, within limits dependent on the steady performance of the watch during the voyage. The value of the marine chronometer as an instrument of precision was soon recognised, and towards the early years of this century had been extensively employed for the measurement of "meridian distances," not only by the leading navigators of the period, but also in the maritime surveys of limited areas then in progress.

Thus we find Smyth in the Mediterranean [1817–24] with five chronometers; Dr. Tiarks [1822–3] establishing the longitude of Pendennis Castle, Falmouth, with twenty-six, and of Funchal, in Madeira, with seventeen chronometers, as measured from Greenwich.† Of our own scientific voyagers, Foster carried seventeen in *Chanticleer*; King [1826] eleven in *Adventure* and *Beagle*; FitzRoy [1831] twenty-two in *Beagle*. "Meridian distances" between places scattered all over the globe were now rapidly accumulating, but there was a want of harmony in rendering their results. The longitude of a place as determined by chronometers is only relative to the longitude of some original starting-point, and it is necessary that the longitude of that original point should be determined either absolutely by astronomical observations, or by accumulated evidence of chronometric connection with a fixed astronomical observatory. From the neglect of this observance, the anomaly frequently arose of two places whose difference in longitude was assured by time measurement, being individually assigned longitudes, the difference between these assigned longitudes being miles wide of the verified amount. The settlement of the longitudes of even well-known and frequented ports was thus a source of embarrassment to hydrographers.

In 1839, Henry Raper, an officer in the Royal Navy of distinguished scientific attainments, whilst engaged in the preparation of his well-known work on navigation, perplexed with the inconsistencies that prevailed, suggested the remedy for

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* In the year 1714 an Act was passed offering a reward of 10,000*l.*, 15,000*l.*, and 20,000*l.* respectively, for a method of ascertaining the longitude within 60, 40, or 30 miles. In 1765 an Act was passed which awarded the 20,000*l.* to Harrison, a mechanician who had constructed a timepiece the performance of which in a voyage to Jamaica and back was well within the given conditions.

† Schubert, in 1833, proceeded round the Baltic Sea in a steam vessel with 56 chronometers, reckoning his longitudes from Altona Observatory. In 1845, the Astronomer Royal measured the meridian distance between Greenwich Observatory and Valentia in Ireland with 30 chronometers.

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this chaotic state of an important geographical question. He assumed that there were then eighteen places fairly distributed over the oceans, the absolute longitudes of which might be adopted as sufficiently accurate, though subject to revision for the purposes of hydrography and navigation; that these places should be known as "Secondary Meridians" (Greenwich Observatory being the primary meridian adopted by English and many other navigators), and that to these secondary meridians the chronometric measurements made in adjacent parts should be referred. For example, the Cape of Good Hope Observatory should regulate the meridians of all the southern coasts of Africa; Madras Observatory, the eastern coasts of India and Bay of Bengal; Batavia Observatory, Java and the adjacent islands; and so on for the eighteen places selected.

Raper well knew that a regulating (or secondary) meridian had already been adopted by a few scientific navigators and in limited surveys; but his object was the general recognition as a principle, which the state of hydrography then demanded. The unity of design here advocated gradually became uniform in practice, discrepancies were reconciled, and difficulties gradually vanished. By the sustained labours of surveying officers and skilled navigators—and in this the officers of our own Navy have taken a conspicuous share—"meridian distances" have greatly accumulated in the last fifty years. This addition to the common stock, together with contributions rendered by the comparatively recent method of conveying time signals by the electric telegraph, and so determining the meridian distance between two places, has admitted of the eighteen secondary meridians originally proposed being with advantage extended: the Hydrographic Department of the Admiralty, for the harmonious regulation of the meridians of its numerous charts, has for some years adopted fifty secondary meridians. At the present time they are thus distributed:—

On the shores of the Atlantic Ocean and neighbouring seas ..	19 in No.
Indian Ocean and Red Sea	7 „
Java, China, and Japan Seas	7 „
Australia, Tasmania, New Zealand	9 „
Pacific Ocean	8 „

Proofs are not wanting of the remarkable accuracy that has been attained in the settlement of the longitudes of distant ports. Within the last five years, under the authority of the United States Government, several places on the American continent and among the West India Islands have been connected by time signals with one of the principal United States observatories, and in some cases with Greenwich, through the electric telegraph. Assuming this method of transporting time to be, perhaps, as practically free from error as may be possible for human ingenuity to devise, the longitudes of the corresponding places, which had been previously adopted by the Admiralty Hydrographic Department for its charts, when reduced to the same spot of observation, compare as follows:—

Jamaica, Port Royal ..	32	seconds of Arc	West of	U.S. measurement.
Antigua, St. John's	13	„	East	„ „
Barbados, Bridgetown ..	30	„	East	„ „
Trinidad, Port of Spain ..	3	„	East	„ „
Para	46	„	East	„ „
Pernambuco	14	„	East	„ „
Bahia	10	„	East	„ „
Rio de Janeiro	29	„	East	„ „
Monte Video	30	„	East	„ „
Buenos Ayres	4	„	West	„ „

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There are grounds for assuming that accuracy of a like character prevails generally over those seas where commerce and its attendant navigation exists; and that any glaring error of longitude position such as would be appreciable in a ship's reckoning, as affecting safety, has ceased to exist over the ordinary navigable parts of the ocean.

This is striking progress in half a century. Reverting to the year 1831, we find then even the longitudes of fixed astronomical observatories in an unsettled state,* and with a few exceptions, chiefly in the West Indies and on the Atlantic seaboard of North America, the longitudes of the chief ports of the world were, judged by a modern standard, in a more uncertain condition.

Oceanic Exploration continued: Deep-sea Soundings.—The exploration of the beds of the oceans in the combined interests of science and commerce is essentially a product of the past fifty years. It is true, that in about the middle of last century the subject of deep-sea temperatures began to attract attention, and several interesting experiments, in what may be even now considered notable depths, were successively made by scientific navigators.† The impetus to deep-sea exploration however, was given by the comparatively recent demand for submarine electrical telegraphic communication between countries separated by seas, or by impracticable land routes.

As a hydrographical fact, when the British Association first commenced its labours, the possible or even probable depths of the great oceans were unknown, and so far as records can be traced, even a depth of 1500 fathoms had not been reached. James Ross, in 1840, during his memorable Antarctic voyage, cleared away doubts as to the practicability of obtaining very deep soundings, and proved that the ocean bed was "fathomable" by obtaining 2678 fathoms some distance to the westward of the Cape of Good Hope. From this time many isolated attempts

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* Cape of Good Hope Observatory, established in 1821, and maintained by the British Government, was, from astronomical observations, originally considered in longitude 18° 23′ 52″ E. of Greenwich—subsequently it was changed to 18° 28′ 45″. [This observatory is now being connected with Greenwich by time signals through the electric cables joining Durban, Delagoa Bay, Mozambique, Zanzibar, and Aden.] Madras Observatory, established by the East India Company in 1787, was first placed in 80° 19′ 58″ E.; changed in 1815 to 80° 17′ 21″, and so adopted as the primary meridian for the Great Trigonometrical Survey of India. Subsequent astronomers [1831-1852] shifted it to 80° 14′ 19·5″; its longitude by electric telegraph carried on from Greenwich is now accepted as 80° 14′ 41″ E.

Singularly enough the longitude, as received for a great number of years, of the Astronomical Observatory at Lisbon, differs eight seconds of time from a recent determination made through the electric telegraph.

† In 1749. Ellis, on a voyage to the N.W. Coast of Africa, experimented at depths of 650 and 891 fathoms.

1773. Phipps' voyage to Spitzbergen: 780 fathoms was reached.

1780. Saussure, off Nice, in the Mediterranean, observed the temperature at a depth of 320 fathoms.

1816. Scoresby, in the Arctic Ocean, reached 730 fathoms.

— Wauchope, near the Equator, in the Atlantic Ocean, reached 1010 fathoms.

1818. Ross and Sabine *obtained soundings*, 1000 fathoms, in Baffin Bay.

1826. Kotzebue and Lenz, in the North Atlantic, reached 1078 fathoms.

1828-29. D'Urville reached 850 fathoms in the North Atlantic, and 1032 fathoms in the Indian Ocean.

1831. Berard, in the Mediterranean, reached 1063 fathoms.

—See Phil. Trans., 1874.

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under varied conditions were made by different navigators to sound the hitherto "unfathomable" sea, and occasionally with success. In 1851–6, the United States Government engaged in a systematic exploration of parts of the Atlantic sea-bed; and by an ingenious device for detaching the heavy sinker attached to the sounding line, small samples of the sea-bottom from great depths were occasionally brought up for examination.

But now came the demand for telegraphic communication; and a knowledge of the depth of the sea and of the nature of the ground on which his cable was to be placed were matters of practical importance to the telegraphic engineer. In the summer of 1857, preparatory to the first ocean telegraph cable being laid between Valencia in Ireland and Trinity Bay in Newfoundland, a powerful war steamship (H.M.S. *Cyclops*, Commander Dayman) was detached by the Admiralty to carry a line of soundings across the Atlantic on the line of nearest distance between these two terminal ports. The service was faithfully executed; in nearly every sounding specimens of the bottom were obtained, the greatest depth recorded being 2424 fathoms. This deep-sea sounding voyage, with its special duties, was the precursor of many more on the part of the British Government: one followed [1858] between Newfoundland, the Azores, and England, in H.M.S. *Gorgon* (Dayman). In 1859, in the Bay of Biscay and Mediterranean sea, H.M.S. *Firebrand* (Dayman). In 1861, between the Færoe Isles, Iceland, Greenland, and Labrador, H.M.S. *Bulldog* (McClintock). In 1862, on the precipitous slopes of the bank of soundings extending from the western shores of Ireland, in H.M.S. *Porcupine* (Hoskyn), the greatest depth recorded was 2350 fathoms. In the central parts of Red Sea, Gulf of Aden, and in the Indian Ocean [1859–67], by H.M.S. *Cyclops* and *Hydra* (Pullen and Shortland). Subsequently, numerous lines of soundings on projected telegraph routes in the Eastern seas were made by our surveying ships there stationed, and more recently on the seaboards of South America and Eastern Africa by the enterprising companies engaged in laying submarine cables.

The voyage of the *Challenger* [1872–6], mainly designed for sounding at great depths, and which in its course traversed many seas; ably supplemented as it was by that of the exploratory German ship of war *Gazelle* [1874–6]; the sounding cruises of ships of the United States in the Pacific Ocean, and in the Caribbean and other waters adjacent to their Atlantic shores; that of H.M.S. *Valorous* from Ireland to Baffin Bay and back in 1875, and again in the seas between Norway and Greenland by the Norwegian war ship *Vöringen* [1876–8], combined with the works above related, have enabled us to form a clear generalisation of the profound depths, of the comparative shallows, and also of the nature of the surface features and animal life of the beds of the three great oceans.*

Thus far the exploration of the oceans below their surface has been considered mainly as aiding commercial enterprise; viewed from the value to general knowledge, we cannot but be struck with admiration, and indeed with surprise, at the many fields of research that have been thus opened to science. Indeed, we appear to have arrived at a new starting-point in reference to many of our conceptions of the physics of the globe.

* When graphically rendered on charts by contour lines of equal soundings, the surface of the ocean beds present extensive plateaux, varied with gentle undulations, generally ranging from 17,000 to 12,000 feet below the sea surface. The great Southern Sea, in its unbroken stretch round the globe, is shallower than the seas in the northern hemisphere; neither does this sea, so far as we now know, present those occasional abyssal depths found in the northern oceans. The greatest recorded depth in the Atlantic, 23,250 feet, and in the Pacific, of over 25,000 feet, are respectively north of St. Thomas Island in the West Indies, and east of Yezo Island, Japan.

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Oceanic Research: Meteorology of the Sea.—The study of this branch of hydrographical science has been much encouraged in the last half-century. The earlier navigators—of whom Dampier must be mentioned with respect—and their followers through successive generations, diligently recorded their experiences of the winds and currents and other phenomena interesting to seamen, in many and diverse regions. The absence, however, of methodical arrangement, and the necessity of generalisation of the copious information thus diffused, was beginning to be felt in the early part of this century.

Rennell, the well-known geographer, was one of the first to break ground in this direction, and his 'Investigation of the Currents of the Atlantic Ocean and of those which prevail between the Indian Ocean and the Atlantic'—a work, the labour of the last twenty years of his life [1810–30], published in 1832 by his daughter—has not been surpassed by later research, whether in the copiousness or accuracy of the data employed, or in the industry and critical skill displayed by the author.

Maury, of the United States Navy, following Rennell, was an indefatigable collector of ocean statistics, as was shown between the years 1848–58, by the publication officially, under his superintendence, of 76 out of some 130 contemplated sheets, designed to embrace, "Track, Trade-wind, Wind, Thermal, and Storm and Rain Charts." These charts were accompanied with descriptive text, which finally, in 1858, expanded to two volumes of some 1300 pages. But Maury's work on the 'Physical Geography of the Sea'—originally published in 1855, and which passed through several editions—is that by which his labours are best known, and which assuredly gave an impulse to the study of the subject among seamen. Abounding in speculation—occasionally, it may be observed, not entirely borne out by the logic of facts—this work conveyed, nevertheless, much solid information, and stamped the author as a man of vigorous and original thought.

It resulted from the zeal and earnestness of Maury, that a Maritime Conference—in which the United States of America and nearly all the states of Europe took part—was held at Brussels in 1853, for devising a uniform system of meteorological observations at sea, and "of concurring in a general plan of observations on the winds and currents of the ocean, with a view to the improvement of navigation, and to the acquirement of a more correct knowledge of the laws which govern these elements." Not the least valuable of the recommendations of the Brussels Conference was that for the general adoption of reliable instruments, especially of barometers and thermometers, to be compared with recognised standards, and their errors thus accurately determined.

Recommendations coming from such a source, and in such a cause, could not but meet with general support; and a meteorological department, attached to the Board of Trade, was established in this country under the accomplished navigator FitzRoy, and transferred in 1866, soon after his death, to the superintendence of a committee selected by the Royal Society. A branch of this department continues in the steady performance of its functions, in collecting and discussing the observations made at sea in ships both of the royal and mercantile marine; and many useful papers, accompanied with illustrative charts, have from time to time been published.* The Indian Government has also done good service in the same direction.

* Wind and Current Charts, in five sheets, for the Pacific, Atlantic, and Indian Oceans (as also a similar series for the Atlantic Ocean), arranged for the use of seamen, were compiled at the Admiralty, from these and other general contributions from various nations, and published in 1872-9. They embrace, chiefly in a graphical form, most of the leading features in ocean meteorology.

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Other maritime nations, especially Holland in relation to its Eastern possessions, have continued to take an active part in following out the Brussels Conference recommendations, and our knowledge has correspondingly been enlarged, but the literature of ocean meteorology—necessarily of a fragmentary character—is becoming voluminous and unwieldy; condensation in the interests of the navigator is desirable: it is to be feared, moreover, that the observations still recorded by seamen are increasing beyond the powers available for their complete discussion. Another generation may perhaps reap the full harvest sown in the present one.

Oceanic Research continued: Revolving Storms.—One of the most useful inquiries in Ocean Meteorology, especially as affecting the safety of ships and their crews, has been that on the nature of "Revolving Storms," familiarly known in the seas which they devastate either as hurricanes, or cyclones, or typhoons. On 10th August, 1831—a few weeks, it may be observed, before the inaugural meeting of the British Association—a severe hurricane visited the island of Barbados in the West Indies, when, from the violence of the wind, 1477 persons lost their lives in the short space of seven hours. An officer of Engineers, Lieut.-Colonel Reid, was soon afterwards employed in the re-establishment of the Government buildings blown down in this storm: his attention was thus directed to the surrounding conditions, and led him to seek for accounts of previous storms, "in the hope of learning something of their causes and mode of action."

In 1838, Colonel Reid published the results of his investigations, 'An Attempt to Develop the Law of Storms, by means of facts, arranged according to place and time, and hence to point out a cause for the variable winds, with the view to practical use in Navigation,' a work which at once became a standard authority. In it he bore testimony to the valuable labours of Mr. Redfield, of New York, whose papers published a few years previously, on 'The Hurricanes and Storms of the West Indies and Coasts of the United States,' were considered by him as the first to convey any just opinion on the nature of hurricanes. Public opinion, in which the Government of the day shared, recognised the practical outcome of these investigations, and the attention of the governors of all British Colonies was directed to the furtherance of the study of these storms.

Piddington, President of the Marine Court of Inquiry at Calcutta, followed in Reid's steps, taking up the cyclones of the Indian and China seas. He published numerous memoirs on these storms [1839–51], as also useful practical rules for seamen. Dr. Thom, in 1845, published a similar inquiry, and for many years Mr. Meldrum, the director of an observatory at Mauritius, has further contributed to the nature of these cyclones.* With a zeal worthy of all praise, these several writers diligently collected facts, and in endeavouring to develop the laws by which such storms are governed, demonstrated the dangerous consequences of neglecting the indications by which they are invariably preceded, and pointed out to the seamen the means by which they may be generally avoided. Seamen have repaid these gifts by habits of closer attention, and in rendering more accurate records of the striking atmospheric changes and movements of the barometer, experienced in these remarkable tempests.

Statistics are still being collected in relation to revolving storms, and some divergent points from the views of Reid and his followers have been raised, but to the broad principles laid down by these original investigators on the "revolving storm" proper of tropical seas little has been added, and those principles and their deductions certainly deserve the confidence of seamen.

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* Dove's 'Law of Storms,' considered in connection with the ordinary movements of the atmosphere (an English translation), was published in London, 1862.

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Temperature of the Sea: Oceanic Circulation.—Among the subjects pertaining to oceanic research, and appropriate for mention in this review, as resulting from the deep-sea sounding operations of late years, are (1) the temperature of the oceans at successive and great depths, and (2), as a necessary consequence of these varying temperatures, the constant circulation of oceanic waters. These are matters of deep and varied interest, connected as they are with the great movements of the surface waters, and their bearing on climate, and the distribution of animal and vegetable life, as also on the art of navigation.

Early observers noted the decrease of temperature with the increase of depth, and so low a temperature as 36° to 37° F. had been recorded by Lenz in Kotzebue's voyage [1823–26], nevertheless it became generally accepted as a physical fact, after the Antarctic explorations of D'Urville, Wilkes, and Ross, that in *all* open seas a uniform temperature of about 39° F. prevailed below a certain depth. Instrumental imperfections had much to do with this erroneous deduction.

An especially valuable series of deep-sea explorations, undertaken at the instance of the Royal Society, was commenced in 1868 by Dr. Carpenter and Messrs. Wyville Thomson and Gwyn Jeffreys, the Admiralty assisting by placing at their disposal small war vessels. These operations, continued to 1871, embraced deep-sea soundings, serial temperatures of the sea-depths and dredging of the sea-bed: they extended along the Atlantic seaboard from the Færoe Islands to the shores of Spain and Portugal, and included both basins of the Mediterranean. The results of these explorations were of great value to many branches of science, and led directly to the *Challenger* expedition. The serial temperatures gave unexpected results; their discussion opened up the subject of oceanic circulation at great depths—which had for some time lain dormant—and formed the matter for much lively controversy, as well as for many valuable essays.*

The cause of the low temperature found in the depths of tropical seas had been discussed by Humboldt in the early part of this century. He considered that the existence of the cold layers in low latitudes proved the existence of an under-current flowing from the poles to the equator; and that in the tropical seas which cover the cold waters from Arctic regions, the mass of waters is in a state of movement. D'Urville [1833], Arago [1838], Lentz [1847], extended the discussion.†

The special attention paid to the construction of the deep-sea thermometers employed in the *Challenger* and kindred expeditions, and the painstaking care bestowed in their extended use, have contributed greatly to clear up doubtful points. We are now fairly assured that in seas within the tropical and temperate zones, provided any given area is not cut off by submarine barriers from a supply of polar water (as is the Mediterranean Sea), the sea-bed is covered with a thick stratum of water the temperature of which is confined between 32° and 35° F. Within the Polar areas this temperature falls to 28°. That this cold stratum in the Atlantic Ocean extends from the Arctic to the Antarctic seas, and that in the equatorial regions of this ocean it rises nearer the surface than in the higher latitudes. That in the Pacific Ocean this stratum extends from the Antarctic seas to Behring's Sea,

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* See especially papers "On the Physical Cause of Ocean-currents," in the 'Philosophical Magazine' for 1874, by Mr. Croll of the Geological Survey of Scotland; and a Lecture by Dr. Carpenter "On the Temperature of the Deep-sea Bottom, and the Conditions by which it is determined," 'Proceedings of Royal Geographical Society,' 1877.

† See an admirable, and to the time exhaustive, paper on the "Temperatures of the Sea at different Depths," in the Phil. Trans. for 1874, by the Professor of Geology at Oxford (Mr. Prestwich).

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but without any uprising of the cold undercurrents at the equator as in the Atlantic.

We have thus in the Atlantic Ocean a deep underflow of glacial water from each pole to the equator. In the Pacific, the cold stratum must be derived from Antarctic sources, for the opening of Behring Strait is too small to admit of an appreciable efflux of Arctic waters. Similarly, in the Indian ocean basin, the cold stratum is derived from Antarctic sources, for a temperature of 33·5° F. underlies the hot surface waters of the Arabian Gulf.

In an inland sea—like the Mediterranean—where a submarine barrier prevents the entrance of the colder layers of oceanic waters, different conditions prevail. The results of observations made by Saussure [1780], by D'Urville [1826], Berard [1831], in the Mediterranean were different from those similarly obtained in an open sea. These early observations have been fully confirmed by those of Aimé [1840–44], Spratt [1845–61], Carpenter [1870–71], proving that in this inland sea, almost an ocean in its extent and depth, the variations of temperature in the surface waters cease at about 1000 feet; and that below that line a uniform temperature of about 55° F. (or the mean winter temperature of the surface) prevails even down to the profound depths of 12,000 feet.

Connecting these facts with oceanic circulation:—of the general movements of the surface waters of the oceans, our knowledge as derived from the observations of seamen is now fairly clear, but of the laws which regulate their connection with the movements of the deep waters there is much uncertainty. This much, however—to adopt the conclusions of an able investigator *—appears assured; that although the ultimate course of the great surface currents may be influenced and determined by the action of the prevailing winds and by the movement of rotation of the earth; those currents which originate or acquire additional force in the equatorial and Polar seas, are intimately connected with the surging-up of Polar waters in the great oceans and of tropical waters in Arctic and Antarctic seas.

Oceanic Research continued: Tidal Investigations.—Connected with oceanic research, there is no subject which has been more indebted to the support of the British Association than that of the "Tides." At its first meeting, the late Sir John Lubbock was requested "to furnish a statement of the means which we possess, or which we want, for forming accurate tables for calculating the time and height of high water at a given place." At the following meeting [1832] Mr. Lubbock rendered a Report on the Tides. It was brief, but conclusive as to the deficient means then existing in this country even for predicting the tides at the two great mercantile ports of London and Liverpool. He stated "that in the earliest years of the Royal Society, some attempts were made to set on foot observations of the tides by some of the active members; but these phenomena have long ceased until lately to excite any attention whatever in this country." Also that "works of navigation and sailing directions supply much information with respect to the velocity and direction of the currents; while the time of high water appears to have been carefully ascertained at very few points only on the earth's surface." As to the general complicated phenomena of the tides, he recalls Laplace's opinion as to certain questions being "la plus épineuse de l'Astronomie Physique," and concludes the report by giving his own opinion that "there is no branch of physical astronomy in which so much remains to be accomplished."

Active efforts appear to have soon followed to remedy the deficiencies referred to; systematic tidal observations had been established at the Royal Dockyards

* Prestwich on "Temperatures of the Sea at different Depths," Phil. Trans., 1874.

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in 1831; during the month of June 1834, and again in June 1835,* simultaneous tide observations were made at the several coastguard stations in Great Britain and Ireland. Mr. Lubbock, with great devotion, applied himself to a discussion of the movements of the London and Liverpool tides; while the late Dr. Whewell (whose "Essay towards a First Approximation to a Map of Co-tidal Lines" was published in the Phil. Trans. for 1833) applied himself to the motion of the "tide wave" in different parts of the ocean, the laws of the "diurnal inequality" of the tide, and the comparison of the observed laws of the tides at certain places with the theory. The numerous papers by these able investigators, published in the Phil. Trans. of the Royal Society and British Association Reports, extending from 1832 to 1851, are of permanent value.

Taking up the subject from its practical side, the Admiralty published its first official tide-tables in 1833, in which the times and the heights of high water were predicted for the ports of Plymouth, Portsmouth, Sheerness, and London; these tables have since been continued annually. In 1835, the predicted tide-tables included six additional ports (one being Brest, on the coast of France), and to afford information as to the processes employed in prediction were accompanied by tables of corrections—resulting from Mr. Lubbock's theoretical investigations—necessary to be applied to a constant value of time and of height as determined from a series of observations made at any particular port.

The standard ports have now increased to twenty-four, and constants of time for other places on our own coasts, which can be referred to these standard ports, extend to 180. The modest beginning of official tide-tables in 1833, contained in twenty pages, has now expanded to over 230 pages, which includes, in addition to all tidal information connected with the British Islands, the ascertained establishment for upwards of 3200 places on the globe, accompanied with the rise of tide at springs and neaps.

In 1848–51, copious reports upon the tides in the Irish Sea and upon the tidal streams of the North Sea and English Channel were furnished by the Admiralty surveyor, Captain F. W. Beechey, after a long series of observations afloat, and published in the 'Transactions of the Royal Society.'

The demands of science have kept pace with the acquisition of recorded facts. In 1867, at the instance of Sir William Thomson, a committee of the British Association was appointed "for the purpose of promoting the extension, improvement, and harmonic analysis of tidal observations." Reports were made in 1868, 1870, 1872, and 1876. Both in relation to theory and practical usefulness, these reports mark great progress; the laws of tidal movements have received considerable development, and their analysis so far advanced that mechanical appliances based thereon have been prepared and successfully employed to facilitate the prediction even of the complicated tides of the Indian seas.†

A second committee appointed in 1877, for the purpose of obtaining information respecting the phenomena of the stationary tides in the English Channel and in the North Sea, is now pursuing its useful labours.

Charts of Magnetic Elements. Concluding Remarks.—Reference was made in

* On this last occasion, with the combined action of other governments, simultaneous tidal observations were made along the shores of Europe from Gibraltar to the North Cape of Norway, and along the coasts of North America from the Mississippi mouth to Nova Scotia.

† In connection with the Great Trigonometrical Survey of India, valuable series of tidal observations have been made at Karáchi, Bombay, and are in progress at other ports in British India.

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the early part of this review to charts of the earth's magnetical elements forming a necessary part of the equipment of seamen engaged in the navigation of iron ships. It would not, however, fall within the scope of this review to record the advances made in our knowledge of the "magnetism of the earth," though it must not be forgotten that it was in the prosecution of oceanic discovery and exploration—and markedly so in the last half-century—that the greatest additions were made.

In 1831, James Ross, in an Arctic voyage of discovery, observed in a region where the magnetic needle stood perpendicular; in other words, he observed on the magnetic pole of the northern hemisphere. In 1839–43, the same intrepid voyager, when engaged in a magnetic survey of the Antarctic seas, during the expedition more than once referred to, observed the high dip of nearly 89°, and thus indicated the near position of the magnetic pole in the southern hemisphere. Since that period, the several surveying expeditions which have left our shores, as also individual navigators, have contributed to one or more of the elements—this in a marked degree by the skilled officers of the late *Challenger* expedition. The rendering of charts recording the magnetic forces acting at the surface of the oceans of undoubted accuracy has thus been gradually attained.

In conclusion, it will doubtless be admitted that this review has shown, that when engaged on any of the branches of knowledge therein recorded, the members of the naval profession have with zeal and intelligence actively shared in the object for which the British Association was established, "the advancement of Science."

On the River Gambia.—By R. E. Cole.

PROCEEDINGS OF FOREIGN SOCIETIES.

International Polar Conference at St. Petersburg. — The International Polar Conference, which in 1879 met at Hamburg and in 1880 at Berne, was held this year at St. Petersburg, in the Central Physical Observatory, under the presidency of M. H. Wild, the Director. The following delegates from foreign countries were also present:—from Denmark (which will establish a Polar station at Upernavik in Greenland), Captain Hofmeyer, Director of the Meteorological Institute at Copenhagen; from Norway (which will found a station at Bosskop, Finmark), Professor Mohn, Director of the Meteorological Institute at Christiania; from Austria-Hungary (which will have an observatory on the Island of Jan Mayen), Count Wilczek and Lieutenant de Wohlgemuth, who is to be the leader of the Austrian expedition; from Russia (which will have stations both at the mouth of the Lena and in Novaya Zemlya), Professor Lenz, President of the Physical Section of the Imperial Geographical Society of St. Petersburg, and M. Jurgens, who, as we have before reported, is to be the head of the Lena expedition; from Sweden (which will undertake an expedition to Spitzbergen), Professor Wijkander, of Lund; from France (which may, perhaps, have a station at Cape Horn), Professor Mascart, Director of the Central Meteorological Bureau at Paris; and from Holland, Dr. Snellen, Director of the Meteorological Observatory at Utrecht.

The following is a brief *résumé* of the proceedings at the different meetings of the Conference:—

August 1st.—In addressing the Delegates present, M. Wild, the President, dwelt upon the great loss which science in general, as well as the International Polar Conference, had suffered by the recent death of Lieutenant Karl Weyprecht, the promoter of the project for simultaneous observations in the Polar Regions, and he afterwards gave an account of the labours of the Commission since the meeting of the Conference at Berne in August of last year.—The programme of the present

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